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# APPEARANCE AND REALITY IN THE THEORY OF RELATIVITY.

TO one who is neither a mathematician nor a physicist has come more and more the feeling that in the intense atmosphere of strangeness and amaze which drifts about the progress of the doctrines of Einstein with their subversion of commonsense beliefs—for the people suffer a reverent shock, as beholding two worshipfuls who mutually blaspheme—there is a fairly constant element of natural but unnecessary misunderstanding. I do not mean that the expounders of relativity have deliberately misinterpreted their thesis or resorted to the easy arts of the stage magician, or even that in the words of the more careful there is more than a human modicum of illegitimate statement. I have no competence to criticize their technical procedure and I receive their conclusions with profound admiration and interest. I do mean, however, that these conclusions are received as meaning what the words would mean in present commonplace acceptation, and lend the tremendous prestige of modern science to philosophical interpretations almost contrary to what seem to me their real implications. It is commonly believed that physicists and mathematicians, by some form of the esoteric magic shrined in laboratories, have scientifically proved that there is no real space or time, that lengths incontinently grow and diminish with motion, that clocks mysteriously but precisely alter their rates, that nothing can possibly go faster than a certain curious but definite number of miles a second, and that some straight lines are not as good as they might be. With the relativity of our senses we are all familiar, but now our 'real' world, with regard to which our senses so often deceive us, becomes likewise unstable; and those who bring the new tidings say no word to allay our perturbation. And how should we expect them to diminish the wonder of their discoveries?

Wonderful they are; but, unless I am fondly mistaken, their philosophic value is as a warning of humility to science, not as a demonstration of the falsity of commonsense. The essence of the matter seems to be that, inasmuch as physics is a science of measurements, and since all measurements are relative, *i.e.*, a matter of ratio, and are moreover not magically registered measurements but achieved by some form of instrument, therefore the influence of the instrument must itself be included or allowed for in the ratio; and further that, inasmuch as no unit of measurement but itself is measured, our ratios can be objective only in the sense of being in terms of the instrument or means of measurement which our situation in the universe urges upon our agreement as the most convenient constant. But so far to forget the initial truth that physics is a science of measurement and hence necessarily relative as to deny the existence of anything stable to be measured is radically unnecessary. Whether there is absolute space, time, or motion, I am sure I do not certainly know; but I do know that if there be, still measurement of them would be as relative as Einstein demonstrates.

We are told, when we find difficulty about the relativity of time, that we must rid our minds of 'subjective ideas.' Now this in a sense is true; but in another sense it precisely puts the shoe on the wrong foot. It is true if we use 'subjective' as opposed to the 'objective' which has the scientific sense of communicable, mutually exact, intelligible. But commonsense more normally opposes 'subjective' to the 'objective' which refers to the 'real thing,' the substantive part of the universe which is the 'object' of my perception but is independent of my peceiving it; and it is just this idea of which I must for the time rid my mind if I am to think along with Einstein. When the ordinary man says that two clocks synchronized will remain so unless defective or interfered with in their working, he means the real clocks as they are apart from any observation. His idea of the clocks is subjective and his idea of a real time is subjective, but the essence of each is that the object thereof is purely objective. When, now, the lecturer on relativity says that synchronized clocks moved apart will get out of step, he means that as measured from any particular point they will register differently. But it needs no scientific wizard come from the laboratory to tell us this. We know it well with regard to sound, and a moment's reflection will grant it with regard to measurement by sight; and that measurement must proceed by some medium no one is apt to deny. Only if a clock synchronized with mine and transported rapidly hence were to continue in step, would I begin to have fears for the time-keeping accuracy of one or the other. The theory of relativity goes further than this, to be sure, as to "the crazy old church-clock and the bewildered chimes"; but so far we need no consternation; and this is the essence of the matter, the rest being an admonition to the physicist to stick to the relative times and not bother about which is right since there is no way for physics to find out.

What in brief is now told the physicist is: Since your measurement involves the transmission of light, the formula must take account thereof. This is not a mere matter of 'correction' for the instrument, but of realizing that some ratio of measurement must be accepted just as a point of reference is accepted, and of accepting the experimental evidence for the independence of the velocity of light—its constancy not as a velocity through the ether but its constancy for all our measurements of it regardless of our motion. This last means that for us the velocity of light interposes between us and any independent discrimination of quantities of time and space. It is the challenging part of the theory.

The culminating paradox of the theory in its "special" form is the thesis that the velocity of light is the maximum velocity, that there can be no greater. Now it seems at first curious that a theory of relativity should eventuate in a statement of an absolute; and there is perhaps no other point in the doctrine so repugnant to commonsense as that one may say: So fast shalt thou go and no faster. The conclusion is deduced with full mathematical rigor from the postulates. But it is deduced because it is assumed in them, and means no more than that any greater velocity would be, in the accepted physical scheme, immeasurable. All that is really said by the theory is that the speed of light is the greatest speed which we can by any human experiment measure or be aware of; many things in the universe there may be going at a greater speed; but for physics they are as if they did not exist. If we were all to lose our sight and begin our construction of physics anew, might not the velocity of sound become the maximum, constant for all observers, another Einstein have to work out new formulas, and Newton's laws much sooner cease to be accurate? It is difficult, to be sure, in imagination to clothe ourselves with the belief that sound is a universal velocity and possible criterion of real motion, or to divest ourselves of the recognition that that familiar air whose passage by us we so directly perceive is the medium of sound; but might not a race born blind conceivably postulate the one and fail to associate the other? And if we were to acquire a new sense, operating at a distance by means of a propagation more rapid than that of light, that velocity would be the maximum, the Einstein formulas would most conveniently be translated into its terms, and Newton's laws would be sufficient through a higher range of values. In short, all measurement must ultimately be in terms of sense; that sense which works with least friction, interference, or retardation is best accepted as our constant; empirically it seems mandatory; and, having been accepted, it must be incorporated in any really exact statement of measurement.

I see no reason to doubt that Isaac Newton, who was no stranger to the principle of relativity, would have readily assented to the statement that his formulations were meant of the real object, which could be reached with a minimum of temporal error by light; and that when dealings were had with velocities approaching that of light, the error would become appreciable and would have to be allowed for. The contention of the relativists is that, since the 'correction' must now be accepted as universal and inscrutable, we should take the measurement and not attempt to go behind the returns.

We are told that velocities can no longer be simply compounded. A resolute commonsense would retort that velocities are actually simply compounded, but that our measurement must take account of the means. If there is a real external movement, it may go serenely on by simple Newtonian compounding; but it is manifestly impossible for measurement to be at once at the point of reference and on the way with the moving object, and any message returning from the object must come by natural means and not by instantaneous magic.

Perhaps the basic portion of the theory of relativity is that dealing with time; and it is significant that this should be developed out of a doctrine of simultaneity, *i.e.*, of the measurement of time. Now the chapters of Einstein's book, *Relativity,* dealing with simultaneity, are the portion where the reader who is not a physicist most feels relieved of the bewilderment of unfamiliarity and assured of his lack of complete agreement. Consider the illustration by which the relativity of simultaneity is arrived at.[1] Simultaneity has been defined as a property of events occurring at points *A* and *B* so that an observer at the midpoint *M* between them visually perceives them at the same time. Now suppose a train of length *AB,* coincident with the line *AB* at the time of the events at *A* and *B* but moving toward *B.* By an observer at the midpoint of the train the events will not be perceived simultaneously. Hence, it is concluded, "events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and *vice versa.*"

Let us fully grant the case as put. Commonsense would never deny it,—would maintain, indeed, that the observer at *M,* the midpoint of the train, being not at the midpoint between the events when he perceived them, would expect them to appear non-simultaneously if he believed them actually to have occurred simultaneously. Einstein would, of course, answer that *M'* is at the measured midpoint between *A* and *B* on the train, that the events occurred at *A* and *B,* and that according to his definition, the same events both are and are not simultaneous according as one is on the embankment or the train. And if we insist that the train has moved in the meanwhile, the retort is that the definition says nothing about motion, and that there is no way to be sure which has really moved, train or embankment. Now this is quite true, and throws us back on the definition. Commonsense would probably first assent to the definition given as a fair empirical test of simultaneity; but after consideration of the subsequent illustration, would claim the right of adding the proviso that the system in question must be at rest relatively to the medium of communication through which the observation is obtained. If, for instance, the observers on the embankment and on the train each had arms long enough to feel the events at *A* and *B*, then, regardless of the time involved in the physiological transmission from *A* and *B* to *M* and *M'* (if the right and left systems worked alike), and regardless of the relative movement of train and embankment, the events would appear simultaneous for both or neither. Or if runners were dispatched at equal speed from *A* and *B* on the train and on the embankment, the runners from opposite directions would either meet or not meet at *M* and *M'* regardless of the then relative positions of those two points. And if sound were taken as our means of communication, no fundamental difficulty would arise, since we would stand by the evidence of the system at rest with respect to the air and correct for the other. The difficulty in the definition as given, and taken simply as an empirical test of simultaneity, lies in the sole reliance upon light, the speed of which relative to an observer has priorly been postulated by Einstein to be unaffected not only by the movement of the source relative to the medium, but also by the movement of the observer. Such being the case, commonsense would be quite satisfied with light as a test of simultaneity only in a system absolutely at rest—and this, of course, we can never determine. Now, since sight is incomparably our fastest sense, and for physics largely our only available means of observation, and since, therefore, we do well to agree—if, indeed, we are not forced to agree—with Einstein in accepting light as the fundamental measurement whereby other velocities of communication must be discriminated; we are driven to confess that our commonsense concept of simultaneity has no place in the accurately computable stuff of physics. Commonsense can then only say: So much the worse for physics. We have no absolute measure of simultaneity. Simultaneous events would appear simultaneous to me if my senses acted through space without lapse of time. Since that is not so, simultaneity can not be strictly ascertained, and the degree of possible approximation will vary with the intervening distance and the relative motion involved. Einstein quite properly replies that for physics as a science of measurement such a concept is of no direct value; and he accordingly defines something which can be measured and calls it simultaneity.

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[1] Einstein, *Relativity, the Special and General Theory,* English edition, 1920; chs. viii, ix.

Now this he has full right to do, and for physics it doubtless must be done. Where the commonsense reader disagrees is as to the dogmatic statement that beyond this, simultaneity can have no meaning for anyone. Along with many scientists, Einstein assumes that the absolute and unique requirement of a definition is to "supply us with the method whereby he can decide by an experiment whether or not" any given instance is an instance of the thing defined, that the only function of definition is diagnostic. For physics this may be so, but only because physics is purely diagnostic,—because within a science of measurement the prescription of measurement gives also the essence of the concept. But the relativists explicitly refuse to confine their definitions to their subject. "As long as this requirement [of exact measurement] is not satisfied, I allow myself to be deceived as a physicist (and of course the same applies if I am not a physicist), when I imagine that I am able to attach a meaning to the statement of simultaneity. (I would ask the reader not to proceed farther until he is fully convinced on this point.)"[1] Who can be so absolute as a relativist?

The failure to discriminate between the commonly accepted fact of the constancy of the velocity of light through the ether, and the hypothesis which results from holding steadfastly to this and to the principle of relativity at the same time has been the cause of much confusion on the part of readers of the literature of relativity. That the velocity of light in free space is independent of the motion of the source is not an original and startling postulate of Einstein's; yet readers are apt to accept this as the meaning of his explanation of the Michelson-Morley experiment, and some of the expounders themselves explicitly give it as such.[2] In that statement there is nothing paradoxical or

[1] *Op. cit.*, p. 26.

[2] *E.g.*, E. E. Slosson, *Easy Lessons in Einstein*, pp. 13 f.

repugnant to current ideas. It is true, indeed, of wave motion in general. And so far is it from accounting for the failure of attempts to measure the motion of bodies relative to light that it was an assumption accepted by Michelson and Morley, and the negative results of that experiment might be accounted for as well by denying the assumption as by extending it as did Einstein. For if we give up the ether and say that the measured velocity of light is independent neither of the motion of the source nor of that of the observer, then, obviously, the Michelson-Morley experiment, in which source and observer were travelling together, would give no evidence of change in the apparent velocity of light due to the motion of either one;—any more than a baseball thrown with equal force back and forth in a closed car would go slower in the direction of the motion than against it. Einstein properly names this received hypothesis of the constancy of the velocity of light in a vacuum as one of the two principles out of which his theory sprang, because of its apparent incompatibility with the other principle, the classic principle of relativity. It does not seem, however, if I may venture to contradict Einstein himself, that there is any logical repugnance here, any more than with sound; unless we accept the ether as an absolute and universal frame of reference, or interpret the principle of relativity as denying the possibility of detecting not merely absolute motion but motion apparently absolute for us,—that is, motion with respect to our field of observation as a whole. After that, to be sure, such an experiment as that of Michelson and Morley, would, if successful, upset the principle of relativity. But that experiment gave negative results only; and Einstein accounted for that *dénouement,* not by denying the postulate as to the constancy of the velocity of light on which it was based, but by a daring extension of it whereby the measure of the velocity of light in space is asserted to be independent not merely of the motion of the source but of the motion of the point of observation. This apparent extension is in reality an interpretation necessitated by holding to both apparently repugnant principles at once. Now the principle of relativity is *a priori* safe from disproof so long as we have to do with relative velocities. It is only when with light we seem to come upon a measurable velocity which is a constant as regards space in general, that we can apprehend the possibility of detecting the motion of a body relative to that constant velocity and, from that, its absolute motion. It is in the resolute adherence to the principle of relativity and to the hypothesis of the constancy of the velocity of light in space that Einstein's uniqueness lies. There seems only one possible reconciliation if both these theses be maintained,—namely, that the velocity of any body relative to the velocity of light is indeterminable, that the velocity of light is the same for all observers regardless of their velocities.

This seems absurdly paradoxical; and from it arise all the relativities of space and time necessary to adjust it to a stable body of measurements. And yet my mind, tainted as it is with "metaphysical reasonings," has the impression that this postulate, paradoxical as it at first seems, need not be left so baldly objectionable to commonsense as most relativists glory in making it, and can, at least in great part, be justified quite apart from its services or necessity to mathematical physics. For it results from the privileged position of sight as our most rapid sense, and its paradoxicality arises from considering light under analogy to lesser velocities which are measurable from above. Or let me put it thus. The doctrine actually came into being to account for the negative results of the Michelson-Morley experiment. I well remember the difficulties I had to understand the dismay those results caused. If the ether were simply a natural medium, why should motion relative to it be dignified as absolute motion? And if the ether were defined as the absolute frame of all things, how should we ever hope to make empirical acquaintance with it? But, passing that by, a plain man who had been made to understand the experiment would probably have said that the apparent explanation was that the earth was absolutely at rest—itself the center of the universe. Why not? There is no insuperable *a priori* objection. But, apart from other experimental difficulties (*e.g.*, the aberration experiments), such a result would be repugnant to all modern scientific prepossessions. Now, actually, Einstein's explanation amounts to just this *plus* a qualification and an extension. Not only the earth but every point of observation is at rest relatively to the ether; or rather, to light, since the ether now becomes a mere imaginative supererogation. That is, every point must always seem at rest for observation. For light, relative though it may or must be in its own nature, is for us absolute, since there is no wherewithal for us to measure it. Yet if we were to acquire a supersense, might not light lose its privileged position, an actual medium—not that extraordinary metaphysical somewhat, the home and solvent of all difficulties, the ether—be discerned as its locus, and its velocity behave itself as other properly supervisible velocities? But then our new messenger would have assumed the rôle of master of relativity.

But what of the 'general' theory? Does it not overthrow the postulate as to the constancy of the velocity of light? It rather dispenses with it. In the general theory we are no longer concerned with direct empirical measure of speed and direction, but with the inferential ascription of 'events' to their position in a four-dimensional continuum of space-time. Into it the velocity of light is *aufgehoben* as into a sort of Bradleian absolute. It suffers acceleration, at least in the matter of direction, in the curvature of its path due to the distortion by gravitation of the space it travels. Our point of view in the general theory must be, not merely purely kinematic and descriptive as in the special theory, but purely descriptive in a more rigorous, non-historical, sense. Time infects our geometry, not oversees it; and force becomes merely its own spatial-temporal manifestation. As a motion physically too rapid to be followed by sense may physiologically be given to us as a completed line, so a light-velocity, too unorthodox to be recognized by the special theory, may in the polymorphous space of the general theory appear as a line which Euclid would denounce as crooked; but, just as in the special theory our measured times and spaces see to it that all light velocities are the same, so in the general theory the space through which that particular line extravagates, having profited by the labors of Lobatchewsky, Riemann, Minkowski, and Gauss, who have taught it much virtuosity since Euclid, sees to it that the line is a geodesic, is a straight line for that type of space. In short: 'materialistic' physics out of the void invoked the ether to bear the contradictions of our indubitable relativity; the special theory of Einstein banishes the too mythic old god, but the inscrutability of all motions relative to light must undertake the expiatory task; the general theory absorbs all into a liquescent geometry which distorts itself in unbaffled security of refuge.

Commonsense has built itself a world to live in; and physics, dealing with the measurement of the quantitative relations of experience, at first accepted that world as an abiding-place for its measurements; but gradually and properly has retrieved attention from that real, objective, and accurately inaccessible world in the interest of its own measurements. The strangeness of the contemporary theory of relativity lies in this: that, whereas Newtonian science accepted—assumed—as the stable elements of measurement, a rigid unit of length and a rigid unit of time and would have to allow where necessary for inaccuracies in the use of these units; Einstein, dealing with a world wherein these corrections are inconveniently frequent and obtrusive if not strictly incapable of elimination, gives up the rigid units of real space and time, and assumes as basic unit, in the special theory the velocity of light whereby space and time units are arrived at, and in the general theory the immediate geometrical relation of events in the four-dimensional continuum of space-time from which the velocity of light is itself derived after the analysis of space and time. That is, Einstein's endeavor is 'critical' in the Kantian sense; an effort to absolve all need for 'sceptical' correction in reaching real, objective units—hypostatized units?—by a vigorous redescent to the actual primitive of measurement. The ancient principle of relativity will *a priori* guarantee that on this basis uniform natural laws will be independent of their mode of expression—will manifest invariant relations through appropriate transformations no matter what the standpoint of measurement. Now, as Dr. Murnaghan has suggested in his egregiously acute essay on the subject,[1] this is an attempt through relativity to reach absoluteness—by admitting universal relativity to secure invariance of relation within the scheme. Just so the Kantian criticism, by exhibiting the phenomenality of the understanding, sought to guarantee phenomenal science. The ordinary physicists, with the absolute motion in the ether, have played the rôle of the 'dogmatists'; Michelson and Morley, that of Hume waking the master analyst from his dogmatic slumbers. Einstein, however, more courageously idealistic than Kant, leaves no thing-in-itself in the background; and as a physicist he is doubtless right, —Kant himself excluded it from science. But is the metaphysical—*i.e.*, the commonsense—question of reality so summarily settled?

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[1] "The Quest of the Absolute," in *The Scientific American Monthly*, March, 1921; reprinted in J. M. Bird, *Einstein's Theories of Relativity and Gravitation*, pp. 276 ff.

Beneath all the postulates so much debated of the Einstein theory are the determining essence of physics as a science of measurement and the fundamental methodological principle of parsimony—both in the form of Occam's razor and in that of the rule of convenience for the purpose in hand. It may well be that for physics 'real' time and space are *entia praeter necessitatem* and that Einstein's formulations are an advance in final ease over all others. The principle of parsimony is equally known to the constructions of commonsense and metaphysics; and it may well be that for commonsense, whose aim is not accuracy of measurement but the achievement, as a background of consciousness, of a universe in which it may act and think and feel and be as far as possible at home, real time and space are not *entia praeter necessitatem.* There is no contradiction until physics assumes the arrogance of a metaphysical lawgiver. This vicious extension of the results of the principle of parsimony within a definite field is not altogether foreign to Einstein himself, and in many of his expounders it is much more obtrusive. The positivism of a century ago, itself a metaphysical assumption, returns in the dazzling armor of the most abtruse physics and mathematics. We are told: "We may indulge in abstract metaphysical speculations to our heart's content, if we be metaphysically inclined; we may not attempt to impose the dicta of metaphysics upon the physical scientist. . . . In order not to be metaphysical, we must eliminate our preconceived notions of space and time and motion, and focus our attention upon the indications of our instruments of observation. . . . Whether . . . it leads us to valid conclusions, or . . . to false ones, metaphysical reasoning is something to avoid." Amen! if this be the advice to physicists when working quite within physics; but it comes with exceeding ill grace from one who has just pronounced: "This argument would be perfectly valid, if there *were* real times and distances; but there are not."[1] If we must indulge in metaphysical conclusions, why be so superior to metaphysical reasons? And we do not need to master the intricacies of the physics and the mathematics to be pursuaded that, in general, no emphasis on relativity of measurement, either the ancient relativity of object to perception or the newer inter-relativity of objects as measured, no matter how elaborate or mathematically validated, can be pertinent to disprove existence or even the desirability as a pragmatic metaphysical postulate of something stable which is measured.

The mathematical formulations by which Einstein has made possible the strict extension of the classic principle of relativity to the whole realm of physics are the work of genius and are of the very greatest importance in the unification of physical theories of time and vastly differing velocities. His doctrine, moreover, is of startling pertinence to the recognition of the essentially explanatory rôle of physics and the relative character of knowledge. But it severs itself from the real world of commonsense, not devours it; and has no necessary effect upon the belief in one real time, one real space, and real motion,—concepts which are as irrelevant to physical measurement as physical measurement is to them. Nor, if we may broaden our 'special' into a 'general' thesis, can any of the more philosophical theories of relativity—in ethics, logic, epistemology, or metaphysics—which like Einstein's are theories of measurement, claim, for all their value and validity as theories of measurement, to be disproof of commonsense realism and absolutism, which rests upon grounds prior if not necessarily antecedent to all measurement. We have ever with us the new mythologists, who, having roused spirits, or postulated a finite god, or suffered an ecstasy, think to exhibit the realities of metaphysic and of religion and to expunge the aloofness of the ultimate; behind them troop the subtler relativists, who, having compassed an equation, demonstrated a ratio, and ascribed a number, proclaim oblivion to all that that is numbered or that cannot be numbered.

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[1] Bird, *op. cit.*, pp. 29, 110, 106.

"What? Must I ever be on the way? Whirled by every wind, unsettled, driven about? O earth, thou hast become too round for me!

"Like tired dust have I fallen asleep on mirrors and window-panes.

"With thee have I broken up whatever my heart revered; all boundary stones and statues have I o'erthrown.

"Where is my home? For it do I ask and seek, and have sought, but have not found it. O eternal everywhere, O eternal nowhere, O eternal-in-vain!"

There was of old another sage whose glory, it is sung, was to have burst the flaming bounds of time and space and laid bare the causes of things. His real intent therein was to free us from the gods. And though the gods lived on and will live in spite of Epicurus, mechanism did free the explanations of science from ulterior interference. Our present far-voyager more literally bursts the bounds of time and space, for his intent is to free us from those very realities themselves. And though they may live on in his despite, he may yet deserve the gratitude of science in having freed that accurate world of relations from the ghosts of irrelevant reality.

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